THE EFFECT OF SODIUM SELENITE AND SELENATE ON THE QUALITY OF LETTUCE

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Abstract

Selenium is essential microelement for humans, animals and some species of microorganisms. In human and animal cells Se incorporates in antioxidative system, but it is toxic at high dietary intake. Selenium enters the food chain through the plants which take it up from soil. Se concentration in plants depends on the chemical form of Se, its concentration and bioavailability in soil and soil microorganisms. The aim of the study was detect the effect of sodium selenite and selenate on yield quality of two lettuce varieties.Two varieties of lettuce plants (*Lactuca sativa*): iceberg lettuce 'Tarzan' and lettuce 'Riga' were grown in 1L pots with peat substratum. Plants during growth season were once treated with 50 mg m^{-2}, 100 mg m^{-2} or 200 mg m^{-2} of sodium selenite or selenate. Control – without treatment. Fresh and dry weight of plants, pigment content in plant leaves, ascorbic acid content and antiradical activity were tested three times during vegetation period. Plants treated with selenium had higher leaves pigment content in comparison with untreated ones. No correlation between selenium concentration and antiradical activity was observed. Ascorbic acid content depended on lettuce variety and selenium praparation. No effect of selenium was observed on plant weight. Accumulation of selenium depended on plant and its variety. Selenium concentration in vegetables correlated with Se dose given to plants. Variants were sodium selenate was used accumulated more Se in comparison with selenite ones.

Key words: Lettuce, sodium selenite, sodium selenate, pigments, ascorbic acid, antiradical activity

Introduction

Selenium is a comparatively rare element, and until the 1950s, this element was considered by most scientists to be only very toxic. It was believes to be responsible for considerable losses of farm animals in parts of US (Reilly, 1998). The microelement selenium is needed for normal functioning of human body because it is part of some enzymes and hormones, interacts with vitamins, participate in oxidizing processes, metabolism of proteins, carbohydrates, and fats. Selenium is part of enzyme glutathione peroxidase, the main part of antioxidative defence system in living cells. Therefore selenium and its compounds have notable antioxidative properties.

The selenium content in foodstuffs depends mainly on its content in plant and animal raw materials, but this, in its turn, is affected by the content of selenium in the soil. The content of selenium in soil is found within a range in the world from 0.1 to 4 mg kg^{-1} (England, Scotland) or from 5 to 1200 mg kg^{-1} (Colombia, Venezuela, China's central districts), that further determines the Se content in the food chain (Combs, 2001; FAO, WHO, 2001; Tan et al., 1991).. In the years 1960, it was already found that Latvia belongs to countries with a low selenium level in the soil. In addition, a large part of Latvian soil is characterized by a high acidity and high content of iron. Thus selenium may form insoluble compounds resulting in a reduced selenium containing ion mobility and bioavailability to plants.

Although Se is not considered to be required by higher plants, there are indications that it shows positive effects on plants. It is known that selenium antioxidant properties can stimulate plant growth (Hartikainen et al., 2000), delay plant senescence (Djanaguiramant et al., 2005), protect plants against fungal infection and from herbivory (Hanson et al., 2003) and protect plants against different types of abiotic stress (Hartikainen, Xue, 1999). Hartikainen et al. (2000, 2001) demonstrated that depending on the dosage, Se has a dual effect on ryegrass and lettuce – at low concentrations, it acts as an antioxidant and can stimulate the plant growth, whereas at higher concentrations it acts as a pro-oxidant reducing the yields. At the higher Se level a significant increase in total chlorophylls also is possible (Xue et al., 2001).

Materials and Methods

Experiments were carried out in spring 2010 at the greenhouse of the Institute of Soil and Plant Sciences, Latvia University of Agriculture for investigation of the effect of sodium selenite and selenate effect on biochemical parameters of lettuce, garden cress and spinach. Two varieties of lettuce plants: iceberg (crisphead) lettuce (*Lactuca sativa* L. var. *capitata* L.) cv 'Tarzan' and leaf lettuce *Lactuca sativa* L. var. *secalina* Alef. cv 'Riga' were grown.
Each lettuce at the phase of 1st true leaf was placed in 1 L vegetation pot with peat substrate *"Biolan for Professional"*, pH_{KCl} 6.5, N 70 mg L^{-1}, P 60 mg L^{-1}, K 300 mg L^{-1} with microelements (Fe, Mn, Zn, Cu and B). Lettuce plants at the stage of 3rd true leave were treated with selenium. Sodium selenite or selenate was dissolved in tap water and calculated dose (table 1) was added to substrate. Experiments were done in 10 replicas.

Table 1

Selenium doses used in vegetation experiments

Dose mg m^{-2}	Calculated selenium dose, µg m^{-2}	Sodium selenite mg per pot	Sodium selenate mg per pot
0	0	0	0
50	170	0.57	0.406
100	340	1.13	0.812
200	680	2.26	1.624

Content of chlorophylls and carotenoides in plant leaves was determined spectrofotometrically in ethanol extract (Гавриленко et al., 2003), antiradical activity with DPPH$^{\bullet}$ (1.1-difenyl-2-picrylhydrazyl) radical (Sroka, 2006), ascorbic acid with 2.6-dichlorphenolindophenol (Ермаков, 1972). The content of selenium was determined by a standard method AOAC 996.16, based on the wet digestion with nitric and perchloric acids, reaction with 2.3-diaminonaphtalene (DAN) reagent and fluorimetrical determination at excitation wavelength of fluorometer at 375 nm and emission at 525 nm. Plants were tested three times during vegetation period once in decade. (1st, 2nd and 3rd decade of May). Obtained data was analyzed with Anova and correlation analyses.

Results and Discussion

Obtained results showed that selenium content in lettuce depended on used selenium preparation, variety of lettuce and sampling time.
Both varieties more intensively accumulated selenium in the form of selenate (Fig. 1 and 2). In average cv 'Riga' accumulated selenate 2.7 times more intensively than selenite, but cv 'Tarzan' 1.7 times. Particularly differences between selenium forms were observed when the largest dose (200 mg m^{-2}) was used. 'Riga' accumulated 5.8 times more selenium, but 'Tarzan' accordingly 2.5 times. Data analyses showed significant differences between selenium preparations. Both varieties varied significantly in their ability to accumulate Se. Lettuce variety 'Riga' accumulated higher amounts of selenium in comparison with 'Tarzan'. In average selenium content in leaf lettuce exceeded iceberg lettuce 2.2 times. (Fig. 1 and 2).
Strong correlation between selenium dose and Se accumulation in lettuce leaves was observed (coefficient of correlation for selenate >0.95, but for selenite ≥0.9).
Rate of selenium accumulation depended of variety. Cultivar 'Riga' accumulated both forms of selenium sharply, therefore Se concentration in the lettuce leaves during all time of vegetation was relatively stable. Iceberg lettuce 'Tarzan' accumulated selenium gently. All treatments promoted increase of selenium concentration in lettuce leaves from 1st till 2nd decade of plant growth after Se application. Higher doses stimulated accumulation during 3rd decade as well. (Fig. 2).

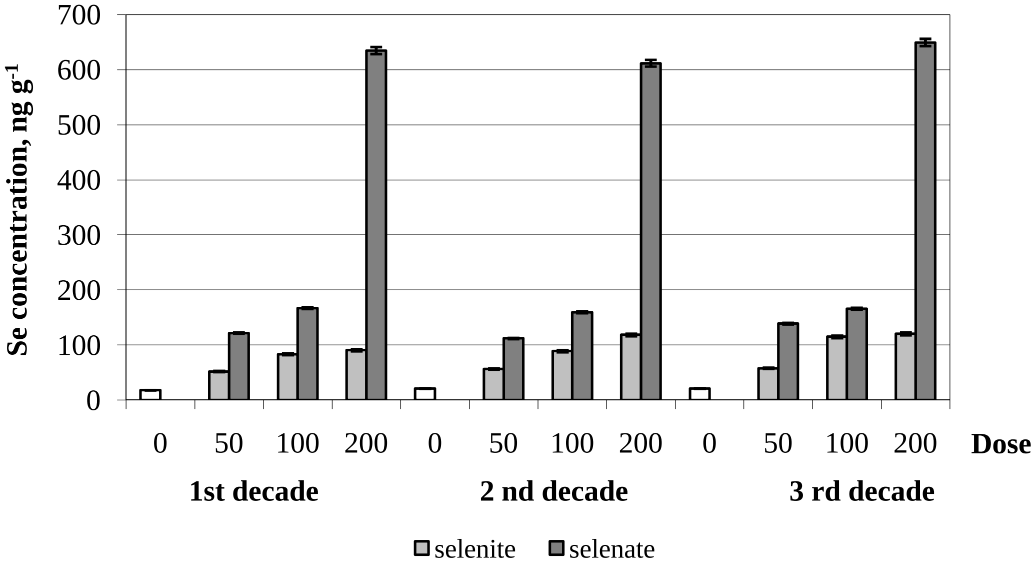

Figure 1. Selenium content in the leaves of lettuce cv ’Riga’, ng g^{-1}

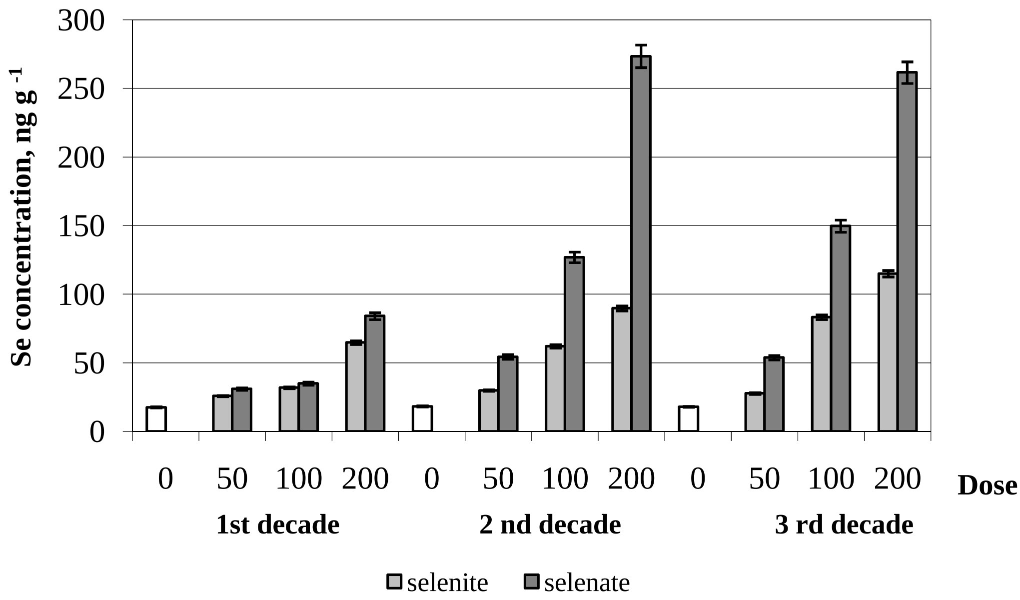

Figure 2. Selenium content in the leaves of lettuce cv ’Tarzan’, ng g^{-1}

In average selenite promoted even accumulation of Se during vegetation in comparison with selenate which uptake was sharper.

Content of chlorophylls depends on lettuce variety, sampling time and selenium dose and preparation (Table 2). In average cv ’Tarzan’ contained 15.4% more chlorophylls as cv ’Riga’. ’Riga’ was less sensitive to selenium treatment. No significant effect of sodium selenite on chlorophyll content was observed. Sodium selenate increased chlorophyll content at early stages of plant development. The significant enlargement of chlorophyll content was observed at 1st and 2nd decade of research as result of sodium selenate dose 50 mg m^{-2}.

Table 2

Effect of selenium treatment on chlorophylls and carotenoides content in lettuce leaves, mg g^{-1}

Sampling time	Se dose	Chlorophylls, mg g^{-1}				Carotenoides, mg g^{-1}			
		'Riga'		'Tarzan'		'Riga'		'Tarzan'	
		selenite	selenate	selenite	selenate	selenite	selenate	selenite	selenate
1st decade	0	0.466	0.466	0.611	0.611	0.120	0.120	0.188	0.188
	50	0.499	0.549a	0.704 a	0.629	0.122	0.140 a	0.206	0.184
	100	0.474	0.589a	0.757 a	0.624	0.113	0.142 a	0.213	0.182
	200	0.499	0.504	0.800 a	0.752 a	0.120	0.139 a	0.248 a	0.245 a
2 nd decade	0	0.505	0.505	0.579	0.579	0.148	0.148	0.185	0.185
	50	0.523	0.606a	0.670	0.661	0.147	0.168 a	0.187	0.187
	100	0.543	0.499	0.651	0.706 a	0.152	0.137	0.180	0.188
	200	0.512	0.492	0.689 a	0.552	0.136	0.186 a	0.236 a	0.195
3rd decade	0	0.668	0.668	0.576	0.576	0.137	0.137	0.124	0.124
	50	0.592	0.636	0.623	0.551	0.136	0.157 a	0.140	0.147
	100	0.571	0.605	0.671 a	0.674 a	0.135	0.136	0.140	0.151
	200	0.618	0.722	0.725 a	0.759 a	0.153	0.177 a	0.156	0.191 a
LSD $_{0.05}$		0.077	0.077	0.092	0.092	0.017	0.017	0.032	0.032

a- Number is significantly higher than control
b- Number is significantly lower than control

Total chlorophyll content decreased during vegetation in the leaves of lettuce cv 'Tarzan'. In average selenium applications delayed that decrease and the most effective was higher doses of Se (100 and 200 mg m^{-2}). Similar results was obtained also with soya (Djanaguiraman, M., et al., 2005) and lettuce (Xue et al., 2001), where effect was described as senescence prevention. At the first decade after lettuces' treatment sodium selenite significantly increased chlorophylls content in the cv 'Tarzan' leaves (Table 2).

Similarly as chlorophylls, no effect on carotenoides content was observed in cv 'Riga' under selenite treatment, but sodium selenate promote carotenoides accumulation in all sampling times as result of 50 and 200 mg m^{-2} Se doses (Table 2). 'Tarzan' is less sensitive and only largest dose (200 mg m^{-2}) significantly increased carotenoides content in lettuce.

Antiradical activity of lettuce leaves depended on sampling time, preparation and its dose and plant variety. In average cv. 'Riga' showed larger activity in comparison with 'Tarzan'. The highest antiradical activity was observed in cv. 'Riga' leaves at the 1st decade of research under selenate treatment and at the 3rd decade under selenium dose 200 mg m^{-2}. No correlation between antiradical activity and selenium dose or selenium content in lettuce leaves was observed (Fig. 3)

Ascorbic acid content in lettuce leaves depended on plant cultivar and selenium application. In average leaves of lettuce cv 'Tarzan' contained 19% higher concentration of ascorbic acid as 'Riga' ones. The elevation of ascorbic acid a**s** the result of selenium treatment was observed for cv. 'Tarzan'. Sodium selenate increased ascorbic acid concentration more efficient in comparison with selenite. (Fig. 4)

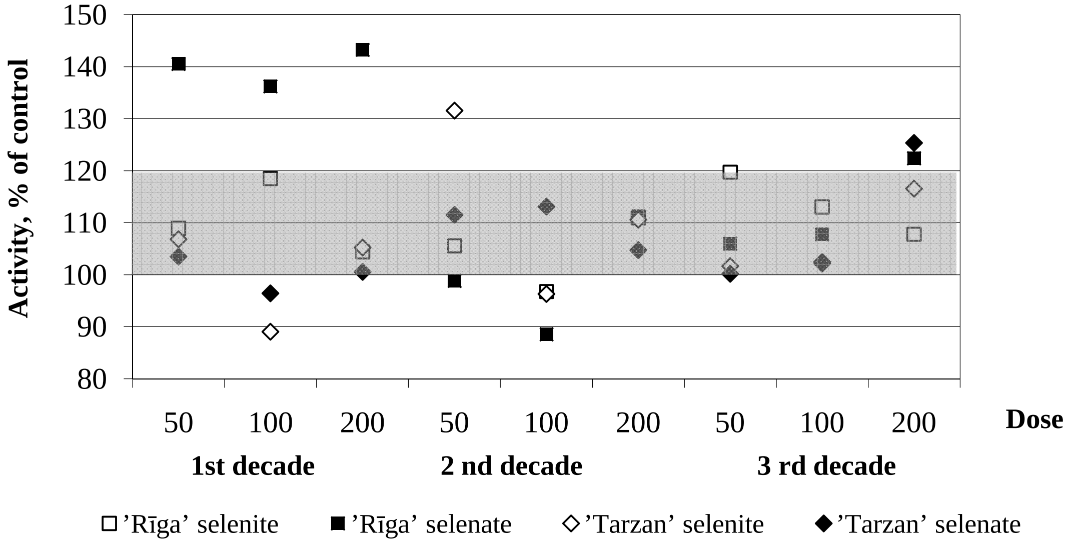

Figure 3. Effect of selenium on antiradical activity of lettuce leaves, % of control

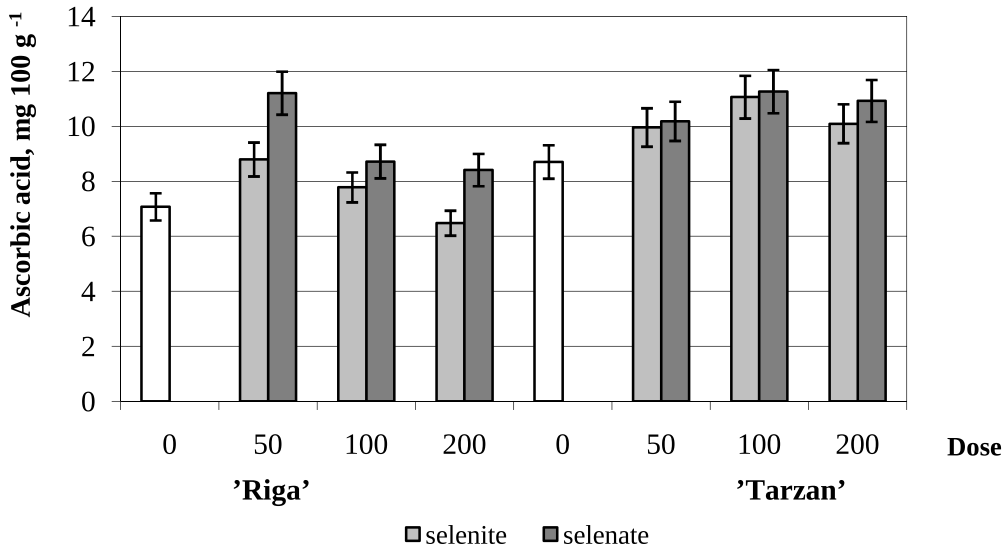

Figure 4. Effect of selenium on the ascorbic acid concentration in the lettuce leaves, mg $100g^{-1}$

The growth-promoting response to Se was not observed for both selenium preparation in opposite to literature mentioned (Hartikainen et al., 1999).

For improvement of lettuce quality sodium selenate is recommended. For leaf lettuce it can be used in concentrations 50–100 mg m^{-2} and earlier (1^{st} decade after treatment) utilization can be suggested. Iceberg lettuce can be treated with larger doses of selenate or selenite and extended utilized

Conclusions

1. Selenium concentration in vegetables correlated with Se dose given to plants. In average lettuce variety ’Riga’ accumulated selenate 2.7 times more intensively than selenite, but lettuce variety ‘Tarzan’ 1.7 times. Therefore for improvement of lettuce quality sodium selenate is recommended and it can be used in concentrations 50–100 mg m^{-2}.

2. Plants treated with selenium had higher leaves pigment content in comparison with untreated ones. In average variety 'Tarzan' contained 15.4% more chlorophylls as variety 'Riga'.
3. Sodium selenate promotes carotenoides accumulation in all sampling times as result of 50 and 200 mg m^{-2} Se doses. 'Tarzan' is less sensitive and only largest dose (200 mg m^{-2}) significantly increased carotenoides content in lettuce.
4. Sodium selenate increased ascorbic acid concentration more efficient in comparison with selenite. The elevation of ascorbic acid a**s** the result of selenium treatment was observed for lettuce variety 'Tarzan'.
5. No correlation between selenium concentration and antiradical activity was observed.

Acknowledgements

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